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Flexural strengthening of RC beams using textile reinforced mortar – Experimental and numerical study

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ABSTRACT

In this paper, the effectiveness of textile reinforced mortars (TRMs), as a means of increasing the flexural capacity of reinforced concrete (RC) beams, is experimentally and numerically investigated. A new type of textile (basalt-based textile) was used as strengthening material. The studied parameters included type of mortar, number of TRM layers and type of strengthening material: TRM versus carbon fiber-reinforced polymer (CFRP) composites. A total of six beams were tested under four-point bending till failure. Two beams were used as control specimens. Three beams were externally upgraded by TRM sheets for enhancing their flexural capacity; and one beam was strengthened with CFRP laminates for comparison with its TRM counterpart. Besides the experimental program, a numerical investigation utilizing nonlinear finite element (FE) analysis was carried out using LS-DYNA software. In addition to the six beams tested in this study, another three beams were collected from the literature for the purpose of finite element validation. A comparison was made between the experimental and numerical results and good agreement was obtained. Based on the validation of FE results, the numerical analysis was extended to include additional cases to study the flexural enhancement of RC beams using more TRM layers with different end anchorages.

1. Introduction

There is an increasing demand in the past years for rehabilitating existing structures due to deterioration and/or the introduction of more strict design requirements. One of the most common strengthening techniques for reinforced concrete members involves the use of fiber reinforced polymer (FRP) composites. The use of FRP has acquired increasing popularity in the civil engineering community, due to the favorable properties possessed by these materials, namely: extremely high strength-to-weight ratio, corrosion resistance, ease and speed of application and minimal change in the geometry [1]. Despite all these advantages, the FRP strengthening technique has a few disadvantages, which are attributed to the resins used to bind or impregnate the fibers [2–5]. These drawbacks may include: (a) de-bonding of FRP from the concrete substrate; (b) poor behavior of epoxy resins at temperatures above the glass transition temperature; (c) relatively high cost of epoxies; (d) inability to apply FRP on wet surfaces or at low temperatures; (e) lack of vapor permeability, which may cause damage to the concrete structure; (f) incompatibility of epoxy resins and substrate materials; (g) difficulty to conduct post-earthquake assessment of the damage suffered by the reinforced concrete behind (undamaged) FRP jackets. One possible solution to the above problems would be the replacement of organic by inorganic binders, e.g. cement-based mortars, leading to the replacement of FRP with fiber reinforced mortars (FRMs). Due to the granularity of the mortar, penetration and impregnation of fiber sheets is very difficult to achieve; also, unlike resins, mortars cannot wet individual fibers.

Bond conditions in cementitious composites could be improved and fiber–matrix interactions could be made tighter when continuous fiber sheets are replaced by textiles [2–5]. These materials comprise fabric meshes made of long woven, knitted or even unwoven fiber rovings in at least two (typically orthogonal) directions. The density, that is the quantity, and the spacing of rovings in each direction can be controlled independently, thus affecting the mechanical characteristics of the textile and the degree of penetration of the mortar matrix through the mesh. A literature review of studies on the use of textiles in the upgrading of concrete structures has revealed the following: the work reported in Curbach and Ortlepp [6] focused mainly on the bond between concrete and cement-based textile composites; the work in Curbach and Brueckner [7] presented test results on RC beams strengthened with two or three layers of alkaline resistant (AR) glass textile combined with cementitious mortar; and the work reported in Triantafillou et al. [2] demonstrated the effectiveness

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of cement-based textile composites in the form of jackets to confine concrete in compression.

In a recent study, Larbi et al. [8] studied the mechanical feasibility of textile reinforced concrete plate for strengthening of RC beams by comparing them with traditional solutions such as carbon fiber-reinforced polymer (CFRP). Three distinct mortar-based composite mixes and two strengthening shapes were used, the U reinforcement and the side reinforcement, and compared with

Table 1
Test matrix.

Beam ID	Type of strengthening material	No. of strengthening layers	Shape of strengthening layers	No. of specimens
BF-1		Control specimen		2
BF-2	TRM with cementitious mortar	10	U-shaped with 40 cm wide and 185 cm long	1
BF-3	TRM with polymer-modified cementitious mortar	5	U-shaped with 40 cm wide and 185 cm long	1
BF-4	TRM with polymer-modified cementitious mortar	10	U-shaped with 40 cm wide and 185 cm long	1
BF-5	Carbon/epoxy system	1	Strip with 10 cm wide and 185 cm long	1
Total number of specimens				6

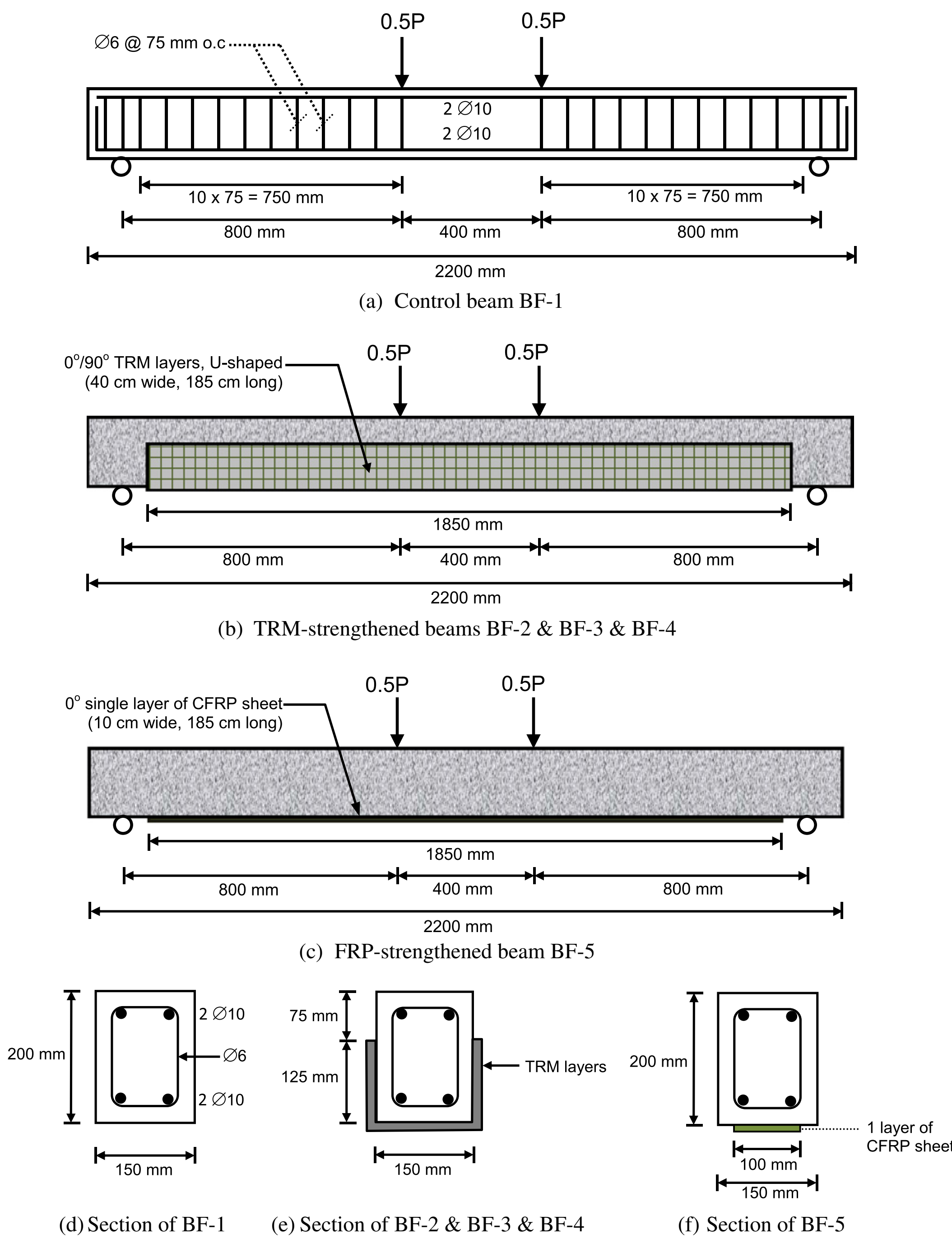

Fig. 1. Details of test beams.